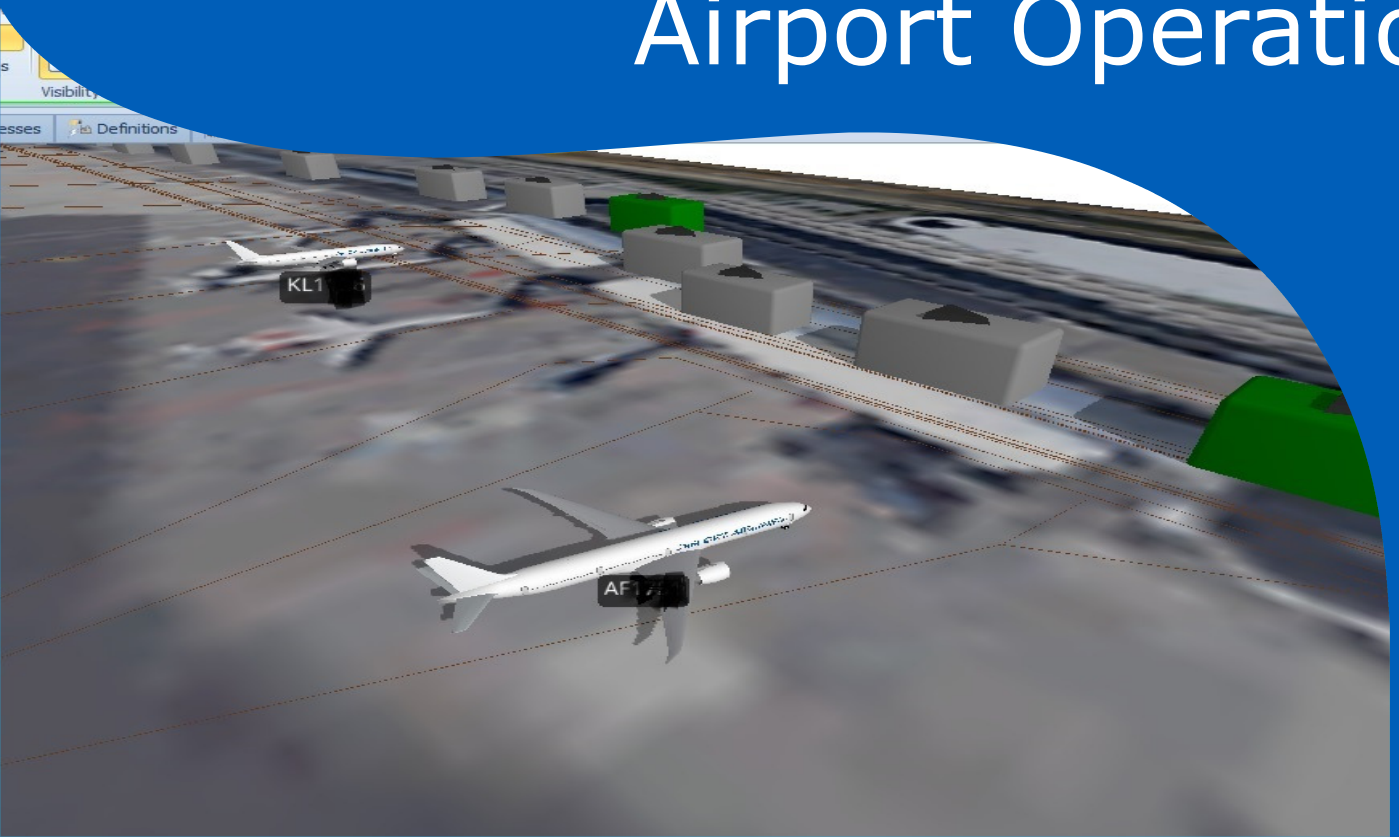
Optimization of Airport Operations



Event:
« Les Pros de la RO »
ROADEF

Rodrigo ACUNA-AGOST
Olivier RATIER

Innovation & Research and Airport IT
Amadeus IT Group
November, 2015

Agenda

- Introduction
- Airport optimization and simulation
  - Stand and gate allocation
  - Runway sequencing
  - Aircraft ground routing
  - Simulator and integration with optimization
- Recognized Benefits
- Conclusions

I) Motivation 

II)What we did 

III)Results 

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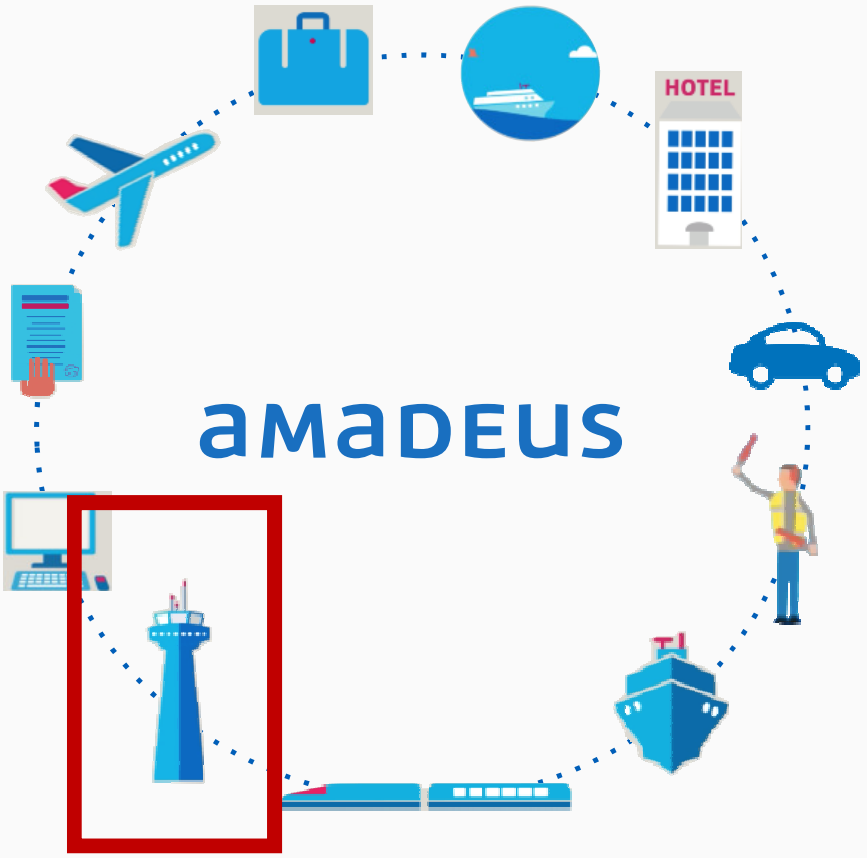
Introduction

Amadeus

- Amadeus is a technology company dedicated to the global **travel** industry
- We are present in **195** countries
- Worldwide, we are **12000+** people
- Our solutions help improving the business performance of: travel agencies, corporations, airlines, **airports**, hotels, railways and more.



Today's presentation = Airports

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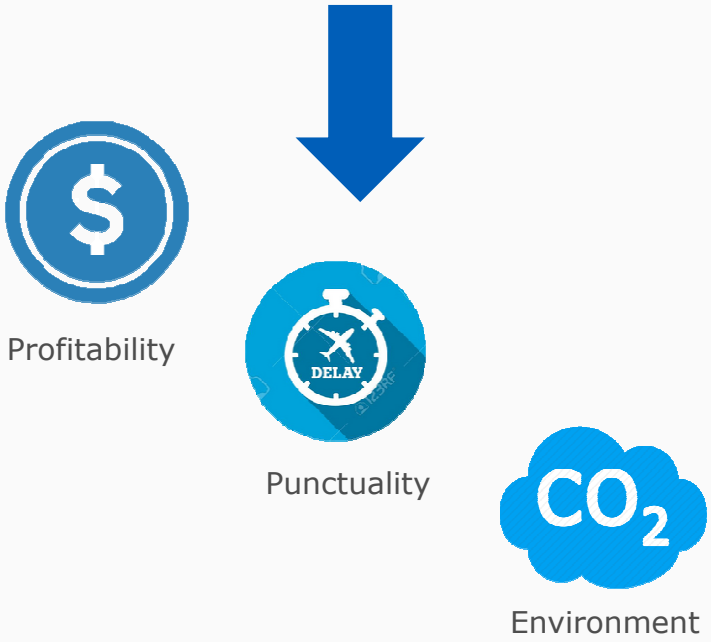
Introduction

Why optimizing airport ground operations?

_ Facts:

- **842 Mi** of passengers/year (Europe)
- **50% more flights** in 20 years
- Main airports are already **congested** in peak hours
- Airport **infrastructure** is very **expensive**, take time, and has ecological impacts
- Airports are responsible of **10%** of total flight **delays** (reference, weather = 9%)
- Cost of delays = 100 to **200 MiEuros/year** (only airport delays)
- Emission at the airport = **50 kg CO_2** / min of taxi time per flight (reference, small city car = 0.05 kg/min)

optimized airport operations



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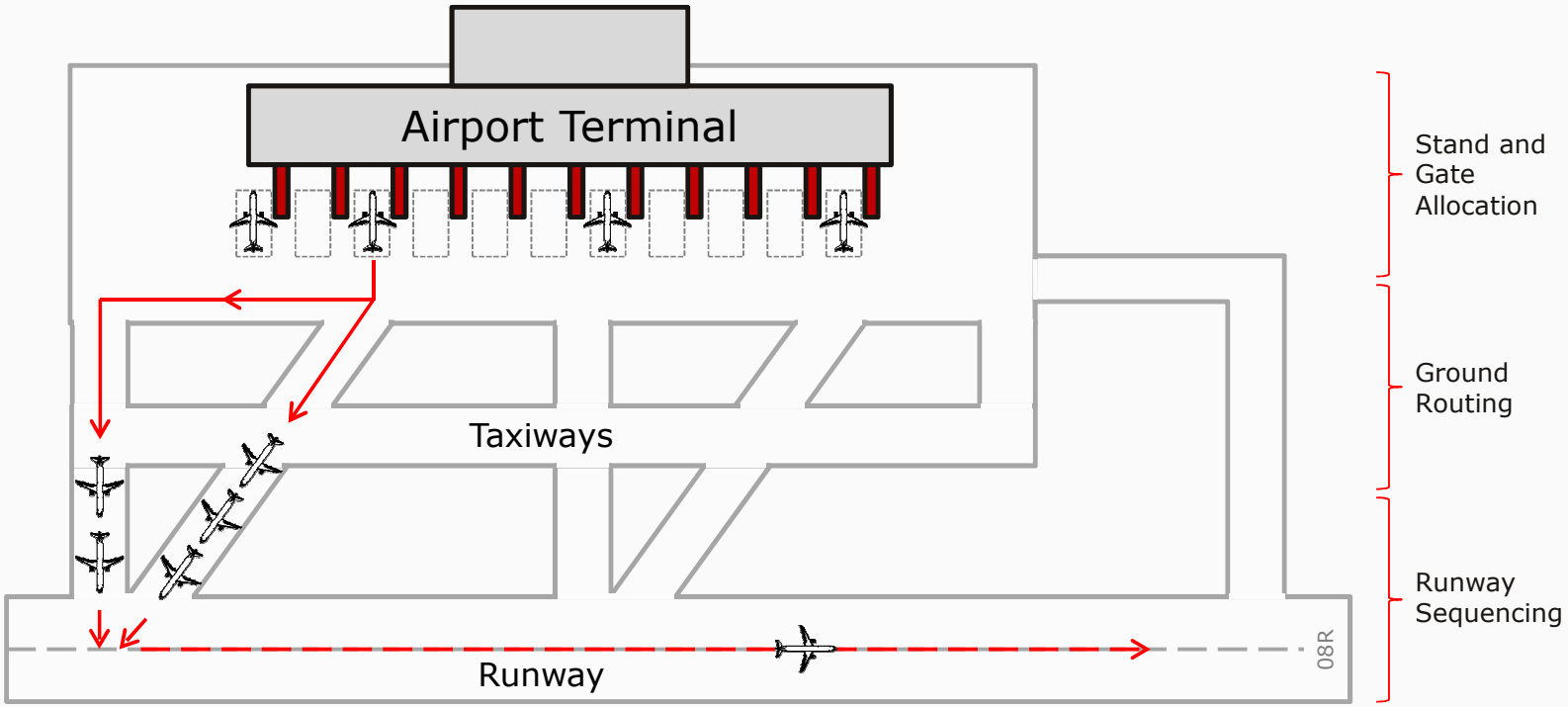
Airport ground resources optimization

Three optimization problems



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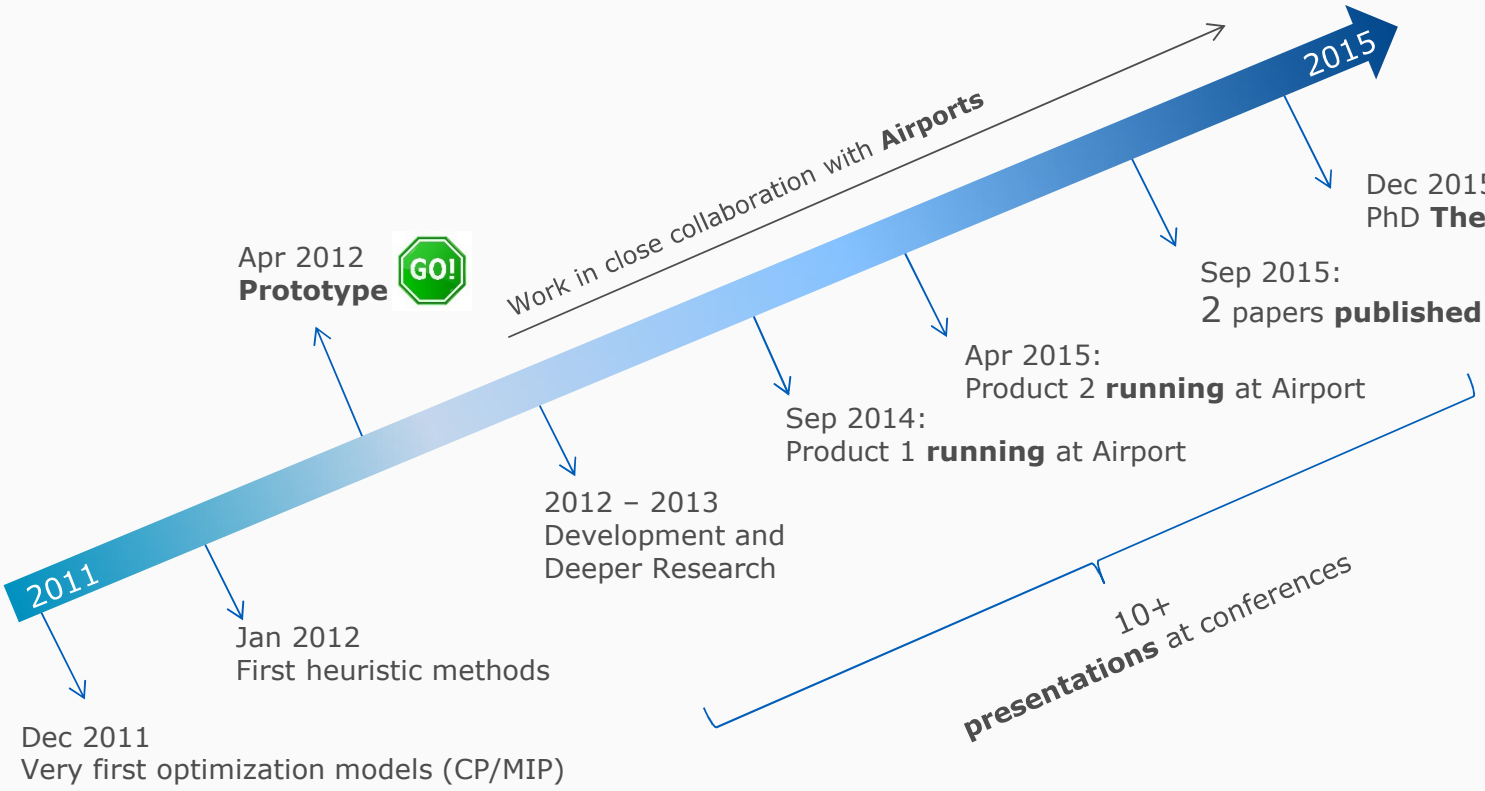
Introduction

Timeline: Research on Airport Operations at Amadeus



Implementation on more airports

10+

contributors

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I) The stand allocation problem

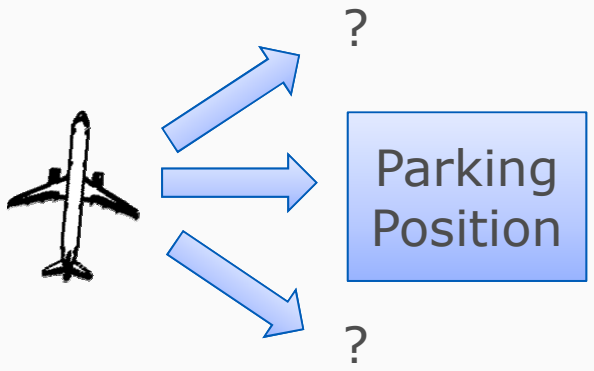
The stand/gate allocation problem

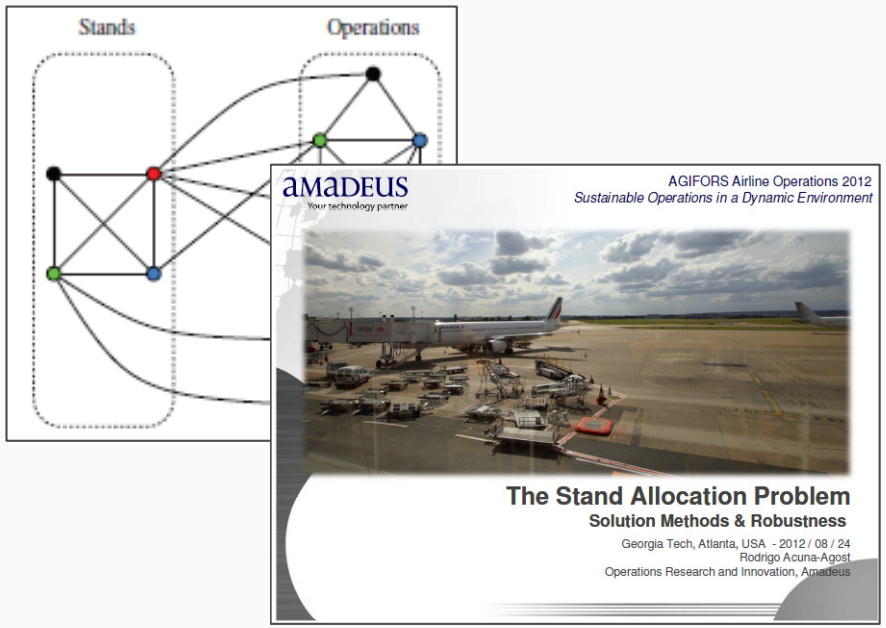
- Problem:
  - **Assigning** aircraft operations to **parking** positions

- Our Contributions:
  - New **formulation** (e.g., European objectives)
  - **10+** solution approaches tested
  - **Proof** of NP-Completeness
  - **Improved** exact and heuristic methods
  - Comparison to the literature:
    2-7% solution improvements

  - **Published**:
    Ref: J. Guépet, R. Acuna-Agost, O. Briant, J.P. Gayon.
    Exact and Heuristic Approaches to the Airport Stand Allocation Problem
    European Journal of Operational Research 2015

  - Conferences:
    - AGIFORS, IFORS, TRISTAN, INFORMS, ROADEF





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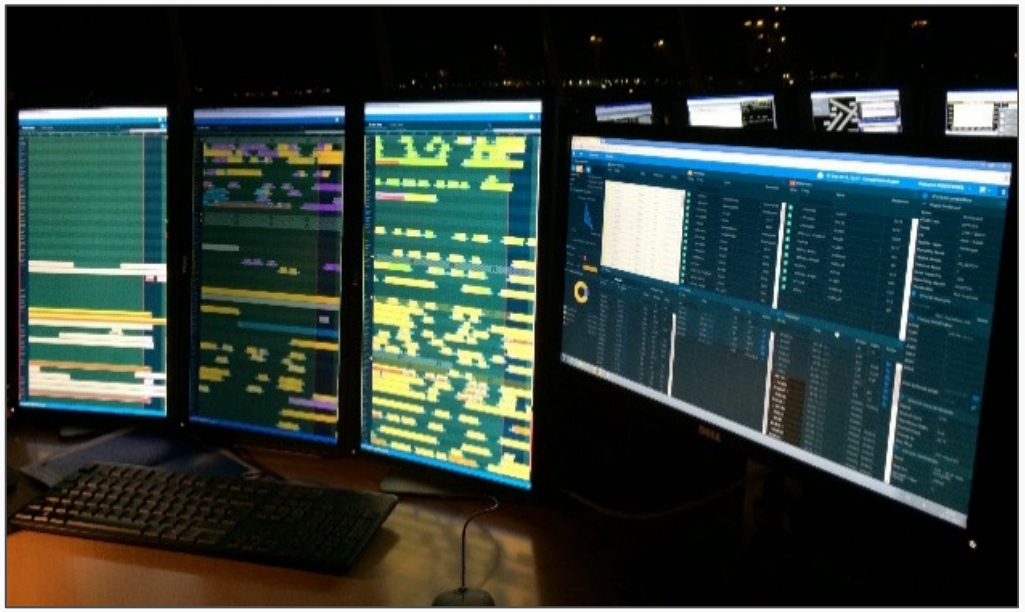
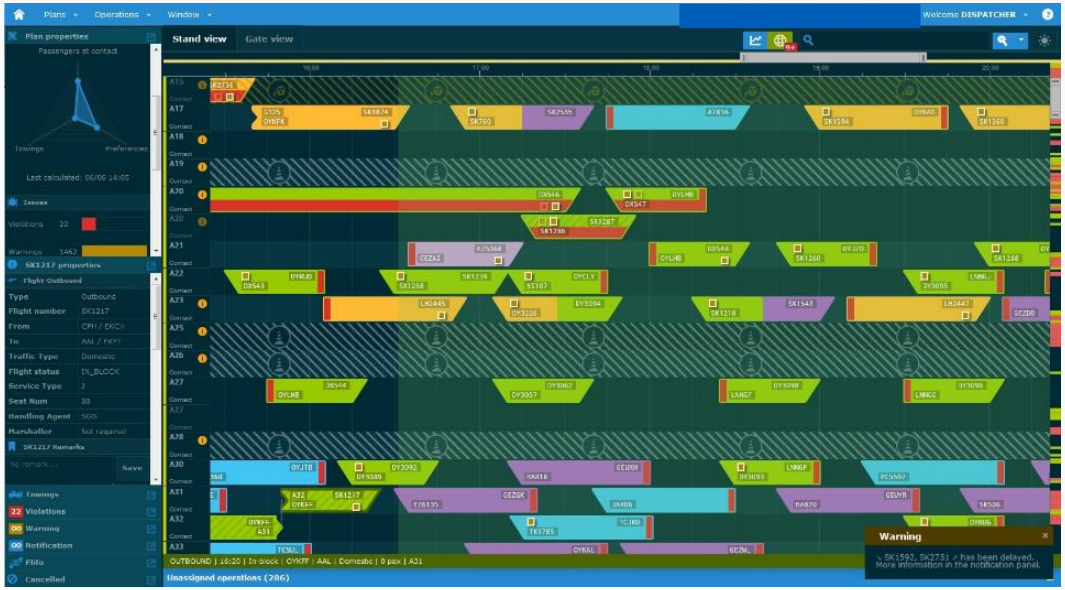
Optimizers running everyday



Picture: Stand/Gate allocation system running in an European Airport
The system runs in 4 screens.



Screenshot: Gantt chart

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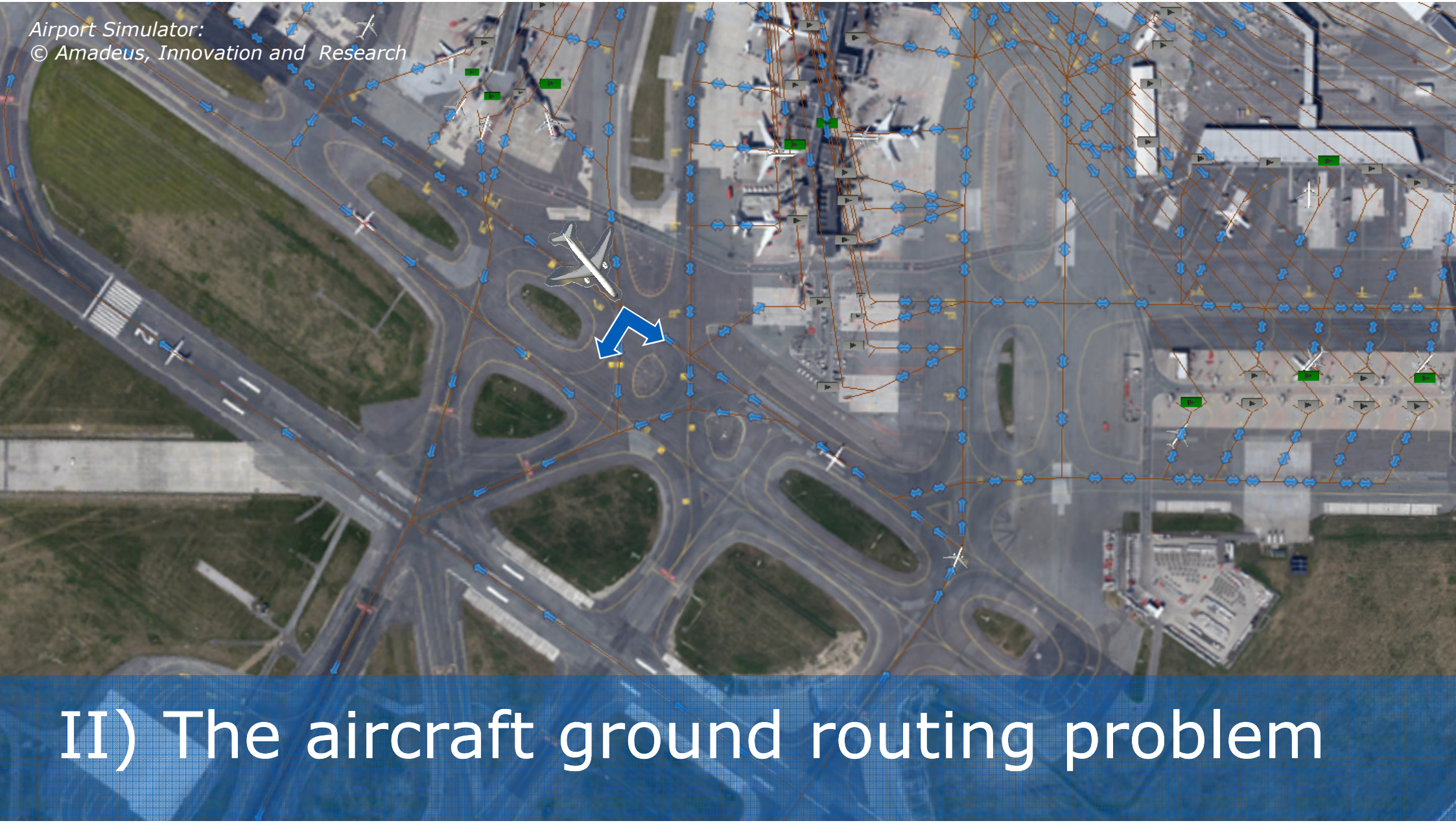
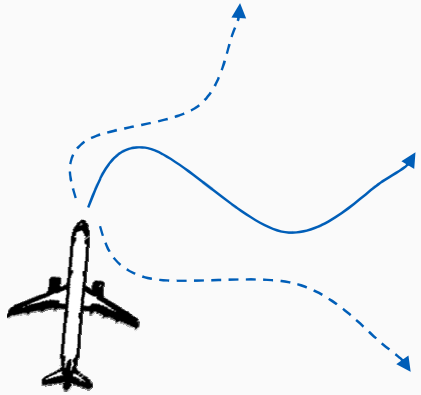


II) The aircraft ground routing problem

The aircraft ground routing problem

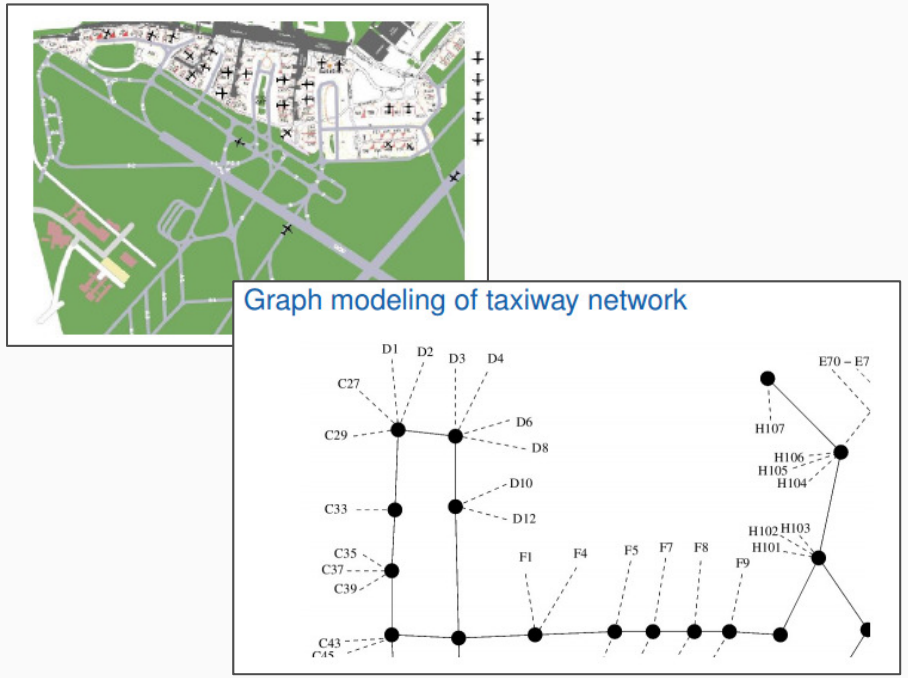


Problem:

- Routing aircraft between runways and stands

Our Contributions:

- **New** exact and heuristic **methods**
- **Integration** of industry indicators: OTP and delay
  (literature models consider total completion and taxi time)
- **Proof** that classical indicators are inconsistent with sustainable scheduling (opposite to taxi time)
- **Published**:
  J. Guépet, O. Briant, J.P. Gayon, R. Acuna-Agost
  The aircraft ground routing problem: Analysis of industry punctuality indicators in a sustainable perspective
  European Journal of Operational Research 2015
- Conferences:
  - AGIFORS, ROADEF



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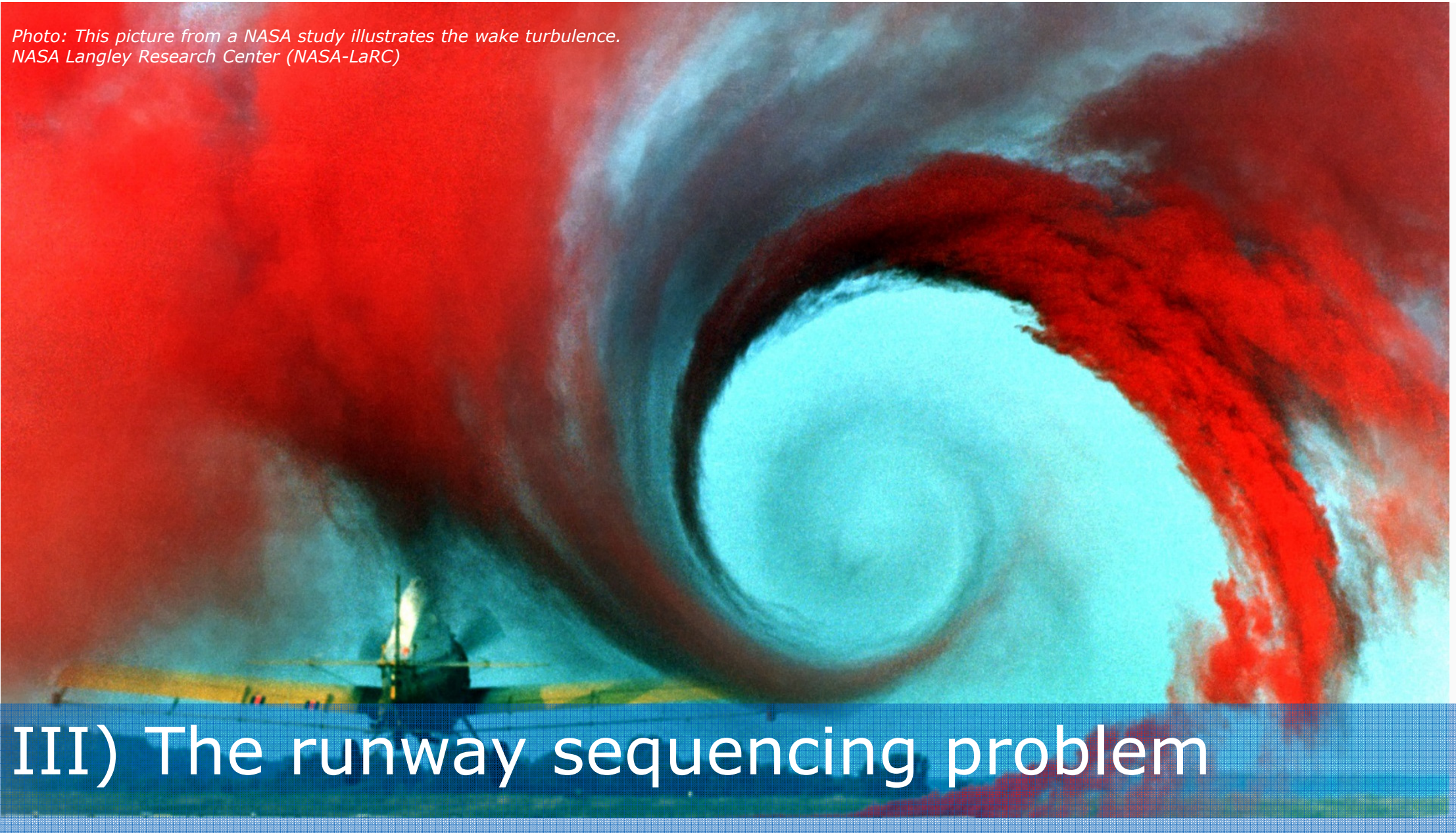


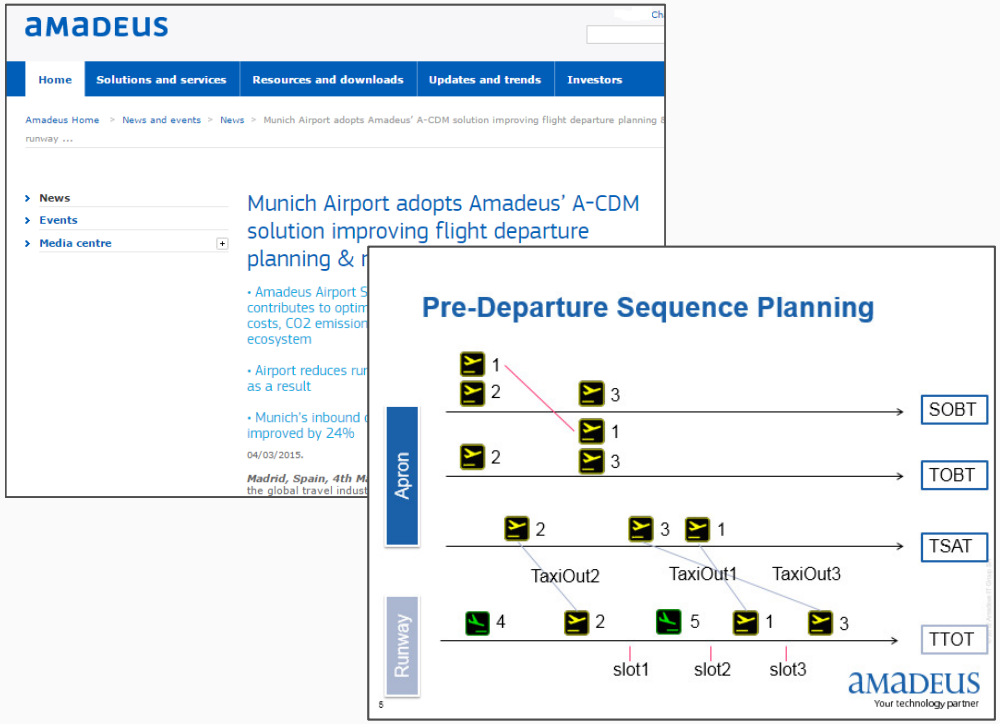
Photo: This picture from a NASA study illustrates the wake turbulence.
NASA Langley Research Center (NASA-LaRC)

III) The runway sequencing problem

The runway sequencing problem

- Problem:
  - **Sequencing** aircraft at the runway

- Our Contributions:
  - **New** exact and heuristic **methods**
  - **Integration** with the ground routing to optimize the whole departure process
  - Propose a model fully integrating both problems and an improved **iterative approach**
  - Conferences:
    - ROADEF, AGIFORS



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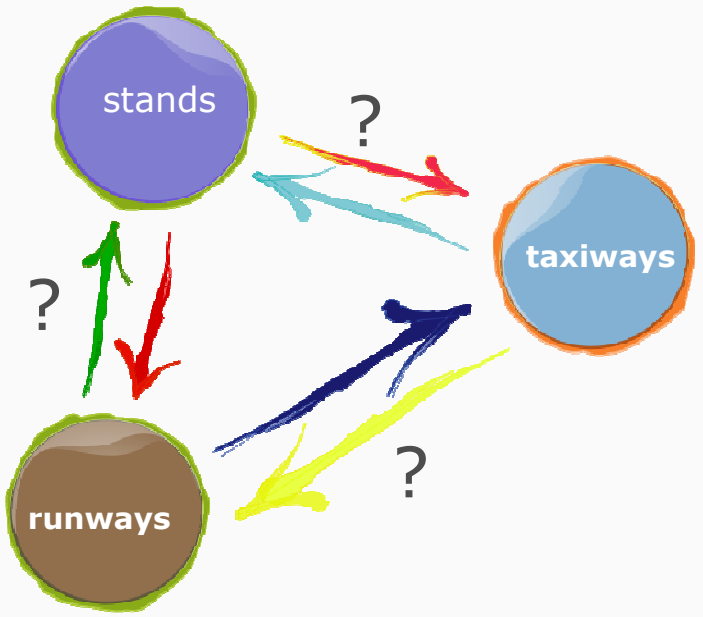
Excellent results on the individual problems …

- what really happens during the day of operations?
- what are the interactions between them?
- what happens if there are disruptions?
- do individual optimal solutions bring overall good operations?



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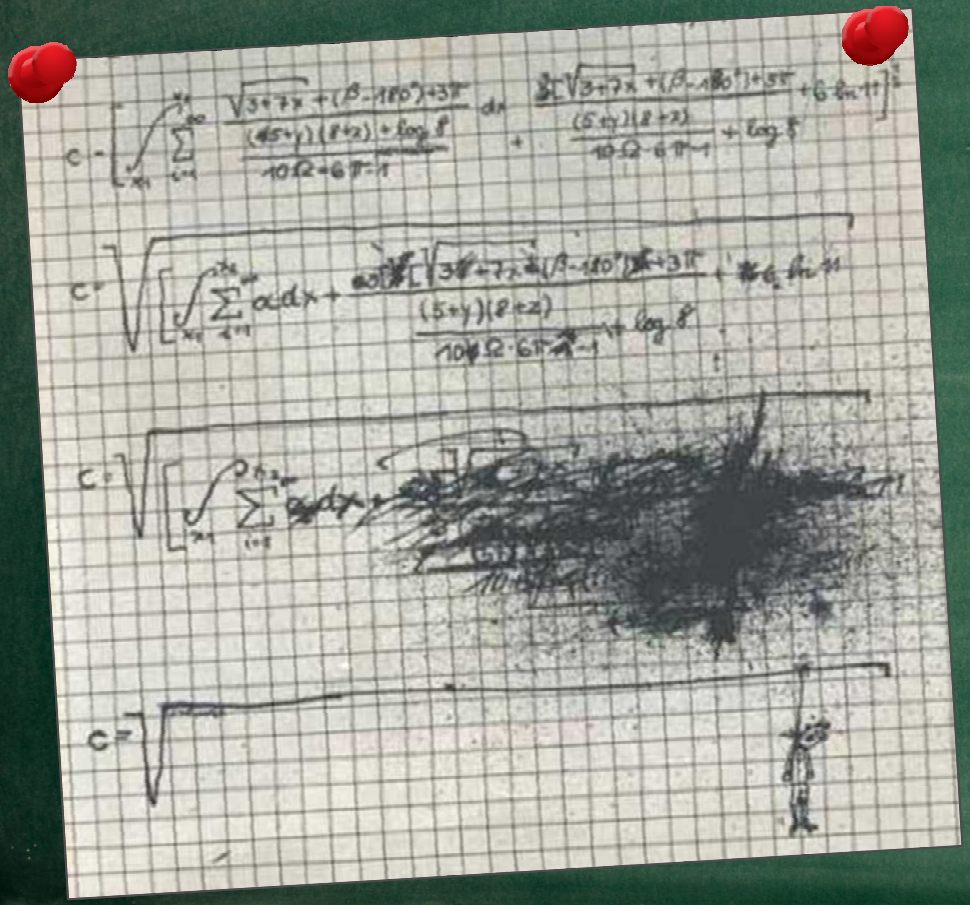
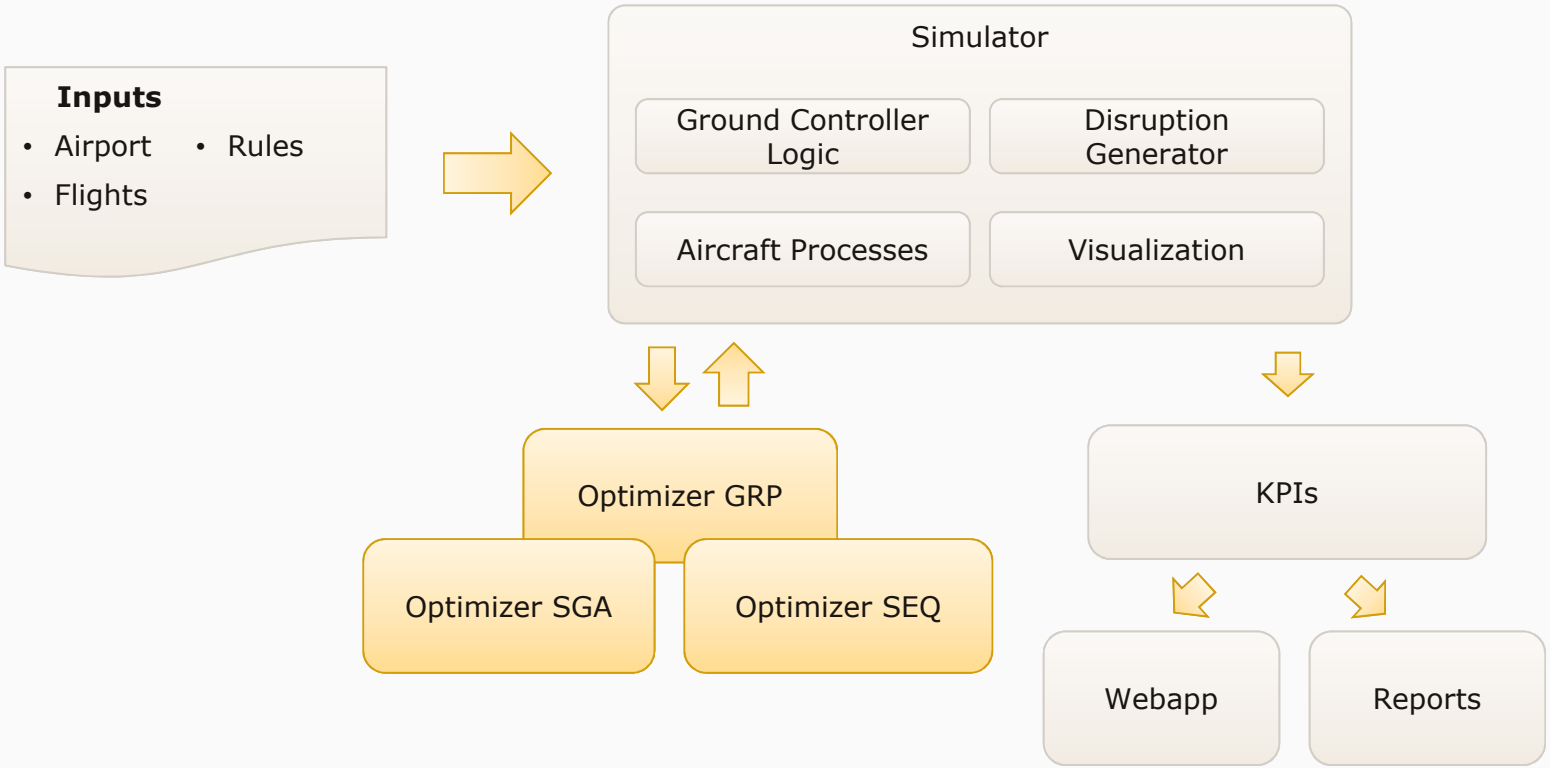
and then we tried analytical solutions ...



... mmm maybe better to try to put everything in a simulator ...

Simulator + Optimizers

Studying the interaction between different optimization problems



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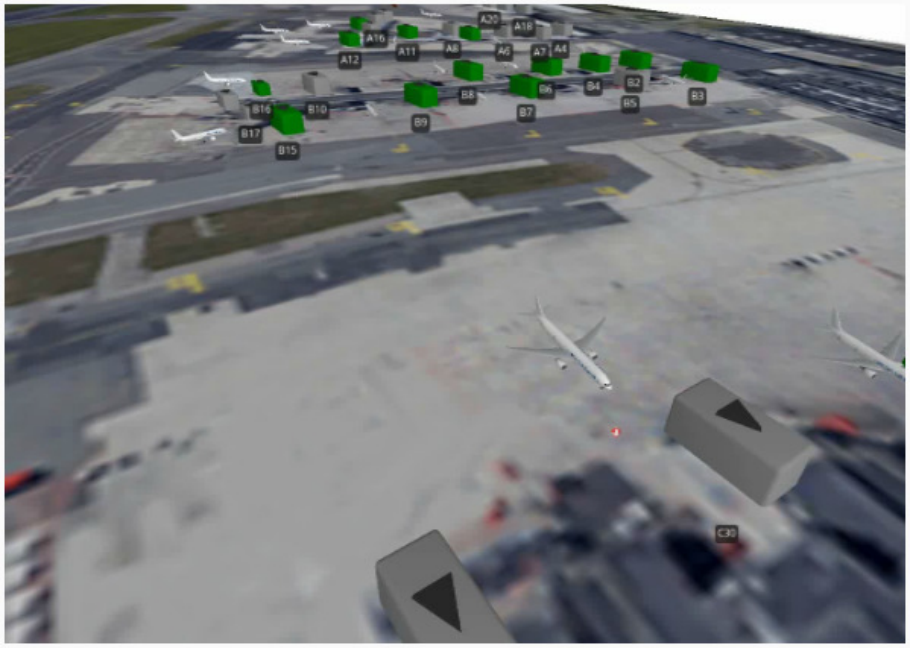
Simulator, 3D view

Some screenshots

Departing Sequencing



Pushback

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Recognized Gains

Achievements

- Optimizers are part of two new **products**
- Software running **every day (second)** in important European Airports
- Several other airports **worldwide** have shown **interest** (still under negotiation):
  Asia, North America, and Europe
- **Published results** (see Figure on the right):
  - Runway waiting time reduced by 50%
  - Improved flight slot adherence by 22%
  - Delays recovery capability improved by 24%
- Monetary gains estimation:
  - See next slide

Press release, March 2015:

Munich Airport adopts Amadeus' A-CDM solution improving flight departure planning & runway capacity

• Amadeus Airport Sequence Manager, part of the A-CDM offering, contributes to optimising airport resources, reducing airlines' fuel costs, CO2 emissions, bringing benefits to the whole airport ecosystem

Airport reduces runway waiting time by 50% limiting fuel wastage as a result

• Munich's inbound delays, compared to outbound flight delays improved by 24%

04/03/2015.

***Madrid, Spain, 4th March, 2015*:** Amadeus, a leading technology provider for the global travel industry, today announces that it has contributed to optimising

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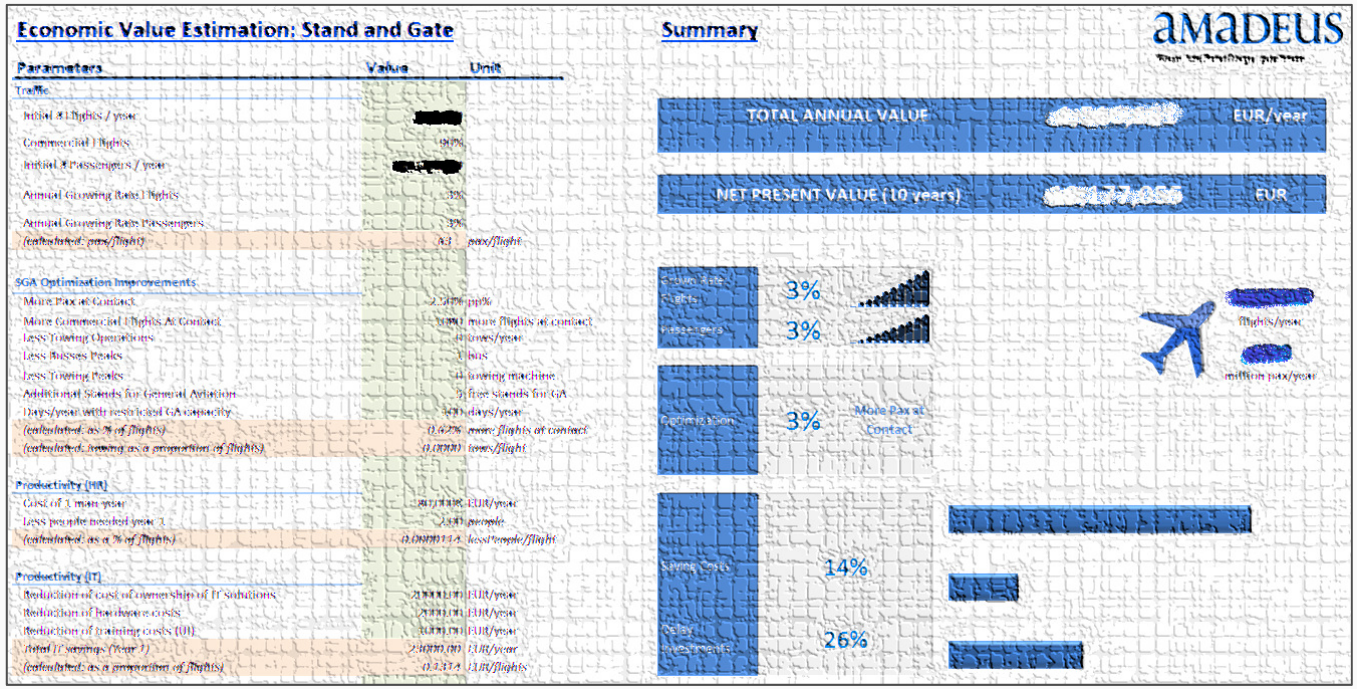
Monetary Gains

Monetary value estimation for Stand/Gate Allocation System

Note: Simulations based on a "standard" airport, actual values cannot be disclosed



Picture: Obfuscate screenshot of the value calculator
Developed and tuned in collaboration with airport experts and real data.

This represents an increase of

~ 1% of yearly profits

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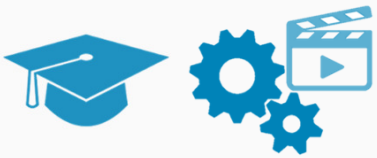
Conclusions

Problem

- Airports are a **bottleneck** of air transportation
- All major European airports are **congested**
- **50%** more flights expected in 20 years
- **10%** of total flight **delays** comes from airports
- 100 to **200 Mi Euros** of airport delay **costs**
- **50 kg** CO2 / minute of taxi time per flight

What we did

- We addressed **3** optimization **problems** and their integration
- **15+** alternative optimization approaches were tested
- **Simulator** integrating several optimizer and visual features (3D)
- 10+ presentations at **conferences**
- 2 published **papers**
- 1 PhD **Thesis**
- 10+ **researchers** have contributed
- Optimizer are part of 2 new Amadeus **products** in the market



Results

- European Airports **using** our tools **everyday** (many others are interested)
- Runway **waiting time reduced** by 50% (real)
- **Improved** flight **slot** adherence by 22% (real)
- **Delays** recovery **capability improved** by 24% (real)
- 1% potential **extra profits** for Airport operators (theoretical)
- 20% potential **reduction** of CO2 **emissions** of taxi time (theoretical)

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Contributors

(alphabetic order)

Rodrigo Acuna-Agost (Amadeus)

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Olivier Briant (Grenoble INP)

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Salaheddine Jouhri (ex-Amadeus)

Dani Perez (Amadeus)

Thilo Pfeiffer (Amadeus)

Olivier Ratier (Amadeus)

Gregoire Spiers (ex-Amadeus)

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Thank You

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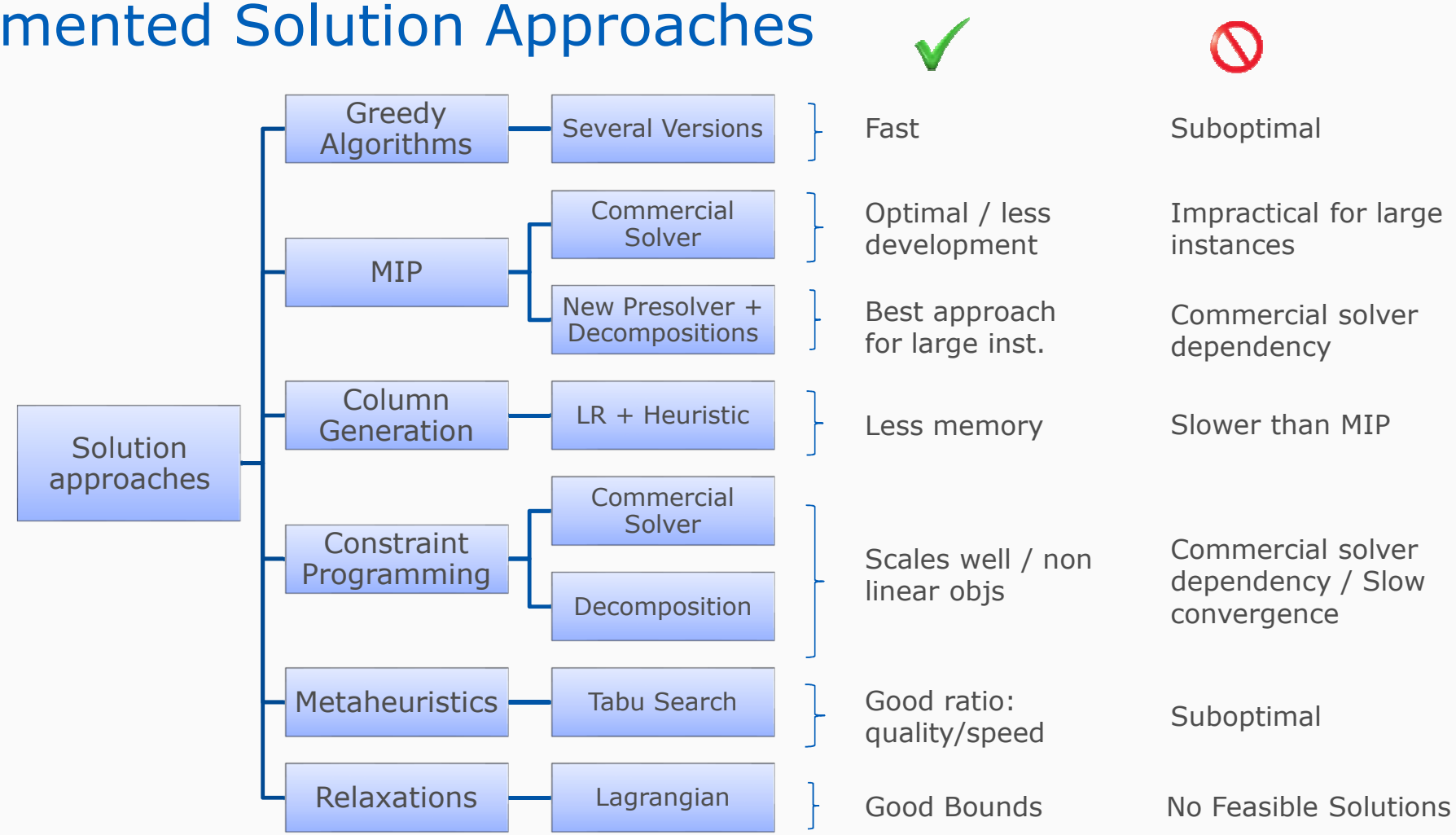
Appendices

Publications

Research Work of Amadeus on this topic

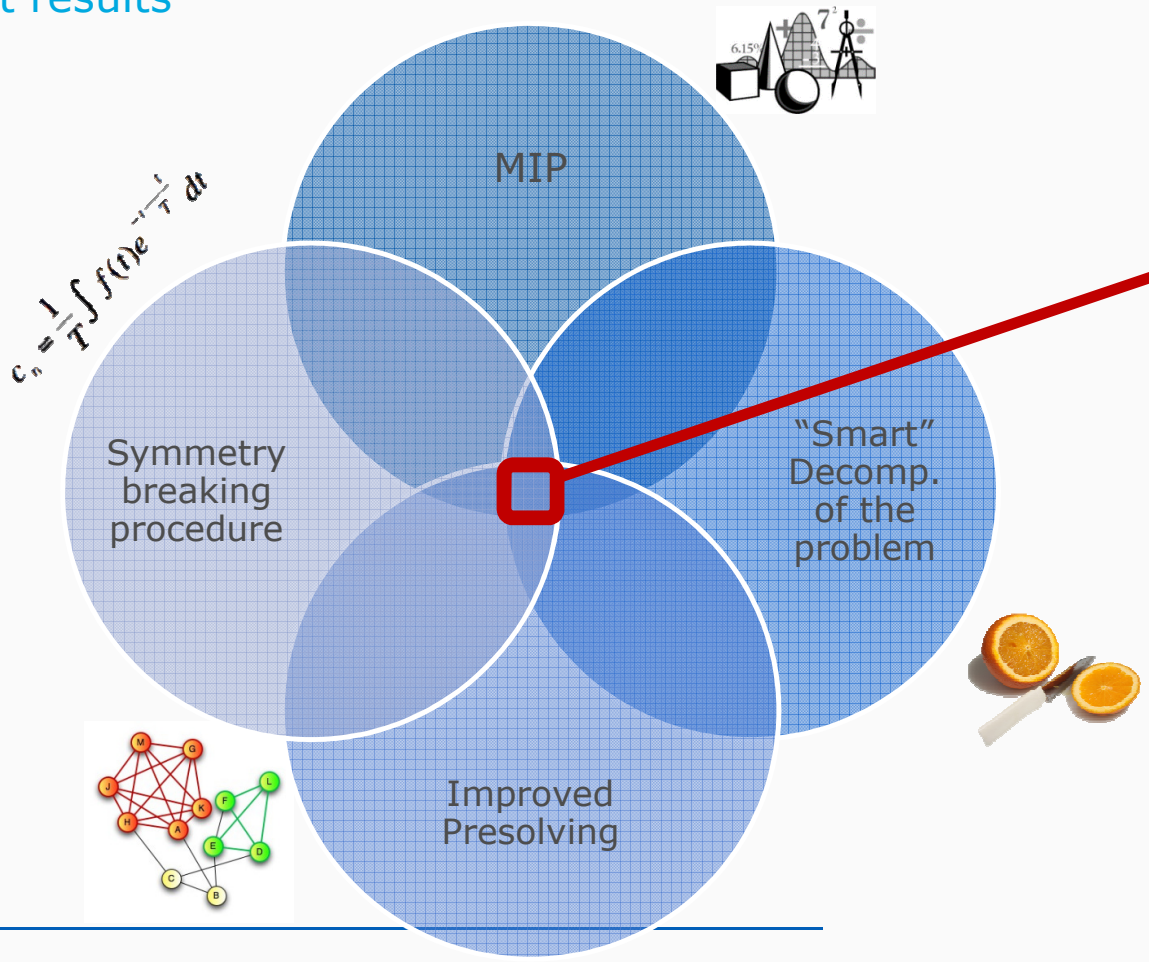
- **Phd Thesis**: Julien Guepet. Reduction de la congestion dans le trafic aérien européen par l'intégration de processus dans les aéroports.
  Tutors: J.-P. Gayon, Olivier Briant, Rodrigo Acuna-Agost. Estimated date: Jan 2016
- J. Guépet, O. Briant, J.P. Gayon, R. Acuna-Agost. *The aircraft ground routing problem: Analysis of industry punctuality indicators in a sustainable perspective*. Accepted for publication in **European Journal of Operational Research** 2015
- J. Guépet, R. Acuna-Agost, O. Briant, J.P. Gayon. *Exact and Heuristic Approaches to the Airport Stand Allocation Problem*.
  European Journal of Operational Research 2015.
- Rodrigo ACUNA-AGOST, Salah-Addine BENMOUSSATI, Thierry DELAHAYE, Julien GUEPET, *Synergistic integration of optimization and discrete simulation techniques for robust airport operations*. AGIFORS Symposium 2015, Washington (2015)
- J. Guépet, R. Acuna-Agost, O. Briant, J.P. Gayon. *Optimisation du routage des avions au sol dans les aéroports*. **ROADEF** 2015, Marseille, France (2015)
- S. Benmoussati, T. Delahaye, R. Acuna-Agost, J. Guépet. *Simulation de mouvements d'avions dans un aéroport avec visualisation 3D. Application à la robustesse de l'allocation de point de parkings pour avions*. **ROADEF** 2015, Marseille, France (2015)
- J. Guépet, R. Acuna Agost, O. Briant, J.P. Gayon. *Comparison of Ground Routing Approaches*. AGIFORS Airline Operations 2014, Panama (2014)
- T. Pfeiffer, R. Acuna Agost, T. Delahaye, S. Jouhri, (in French) *Intégration du problème du prépositionnement d'avion au poste de parking et portes d'embarquement en minimisant le risque de connections manquées*, **ROADEF** 2014, Bordeaux, France (2014)
- J. Guépet, R. Acuna Agost, O. Briant, J.P. Gayon, (in French) *Le probleme de routing des avions au sol*, **ROADEF** 2014, Bordeaux, France (2014)
- Rodrigo Acuna-Agost, Daniel Perez and Julien Guepet. *An Exact Solution Approach for the Airport Stand Allocation Problem*. TRISTAN VIII, San Pedro de Atacama, Chile (2013)
- J. Guépet, R. Acuña Agost, O. Briant, J.P. Gayon, D. Perez, *The Airport Stand Allocation Problem: A Posteriori Guaranteed Methods*, **ROADEF** 2013, Troyes, France (2013)
- Rodrigo Acuna-Agost, Thierry Delahaye, Julien Guepet, Daniel Perez. *Stand Allocation in Airports - New Solution Approaches and Results*. INFORMS Annual Meeting, Phoenix AZ, USA (2012)
- Rodrigo Acuna-Agost, *The Stand Allocation Problem: Solution Methods & Robustness*. AGIFORS Operations 2012, Atlanta, USA (2012)
- Semi Gabteni, Rodrigo Acuna Agost, Olivier Ratier, Thierry Delahaye. *Operations Research for Airport Operations - Achievements and Perspective*. **ROADEF** 2012, Angers, France (2012)
- Mourad Boudia, Baptiste Chatrain, Olivier Ratier. Pre-departure Sequence Planning, INFORM Annual Meeting, Phoenix AZ, USA (2012)

Implemented Solution Approaches



Implemented Solution Approaches

One of the best results



Improvements:

- 100 times faster
- We can deal with huge instances CPU < 1 minute
- Optimal Solution => Gap = 0%

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